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On the Proper Motions of certain Fundamental Stars.

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As Dr. Chandler and Professor Newcomb have been lately discussing the question of Auwers' proper motions, *A.J.*, Nos. 364, 365, it appears a favourable opportunity to give the result of the discussion of some values of proper motions derived from the Greenwich observations, 1836–1893. The particular object in view at the time was to find a number of stars which had been consistently and continually observed over an extended period; but it was soon discovered that there were but few stars which could be so classed. Some were well observed at the beginning of the period, but not at the end, and *vice versa*; while others had awkward gaps at intermediate intervals. At present only thirty-six stars have been dealt with, and some of these can by no means be considered as fulfilling the wished-for conditions.

The right ascensions here dealt with were observed with the transit instrument from 1836 to 1850, and with the transit circle from 1851 to 1893. They have all been reduced to the epoch of 1890, and to the equinox of the 1880 Catalogue according to the following table, with Auwers-Bradley proper motions and Peters' constants of precession.

TABLE I.

Corrections to reduce Greenwich Observations 1836–76 *to the Equinox of the* 1880 *Catalogue.*

Year.	Name of Catalogue.	Corrections to		Year.	Name of Catalogue.	Corrections to	
		Catalogue R.A.	Annual Mean R.A.			Catalogue R.A.	Annual Mean R.A.
		s	s			s	s
1836	1840 Cat.	+·055	−·026	1848	1850 Cat.	−·010	+·062
1837			−·021	1849			·000
1838			−·031	1850			·000
1839			−·030	1851			·000
1840			−·031	1852			·000
1841			−·035	1853			·000
1842	1845 Cat.	+·010	−·011	1854	1860 Cat.	−·003	−·003
1843			+·078	1855			−·003
1844			+·066	1856			−·013
1845			+·087	1857			−·013
1846			+·048	1858			−·013
1847			+·060	1859			−·013
				1860			−·013
1861–67	1864 Cat.	+·007	−·003	1868–76	1872 Cat.	·000	·000

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The residual proper motion was therefore a direct correction to Auwers' values, and its amount was obtained in most cases by plotting every year's result and drawing the best straight line through the series. In those cases, therefore, where the correction to the proper motion is described as ^{s}·0000 it is to be inferred that the observations were practically satisfied by the value found by Auwers. Out of the thirty-six stars twenty-three showed sensible corrections, which are mostly plus for the first twelve hours of R.A., and between declination −16° and +16°, and minus for the last twelve hours of R.A., and between declination +16° and +52°.

The north polar distances were observed with the Jones and Troughton circles 1836–39, with the Troughton circle 1840–47, with the Troughton and Jones Cape circle for the year 1848, with the Troughton circle 1849–50, and with the transit circle 1851–94.

The observations of 1836–47 have been reduced to colatitude 21″·83, those of 1849–50 to colatitude 21″·94, and those of 1851–93 to colatitude 21″·90. The observations 1851–93 have been further corrected where necessary to reduce them to Bessel's refractions, flexure =·000 and formula for R−D $=a+b$ sin Z, which latter correction practically implies that the value of the flexure is determined from positions of the instrument in constant use for observations in preference to the value obtained from a position which is never in use for observation (*i.e.* the horizontal position on the collimators), though theoretically the two values ought to be the same. In addition, corrections have also been applied for the wear in the microscope micrometers 1868–78. No corrections have been applied for Dr. Chandler's latitude variation.

The observations have all been reduced to 1890 with Auwers-Bradley corrections for proper motion, and Peters' constant of precession, and the annual results plotted down, and in most cases the best straight line drawn through the series represented the resulting proper motion, which is the direct correction to Auwers' value, and ″·00 is therefore to be considered as the sign that the Greenwich observations show no sensible corrections to the values found by Professor Auwers. Out of thirty-six stars twenty-three showed sensible corrections.

In *A.J.*, Nos. 313, 315, and 320, Dr. Chandler has rediscussed the observations made at Greenwich with the mural circles by Troughton and by Jones for the years 1825–48, and in *A.J.*, No. 361, he has found for thirty-four of these stars new values of proper motions from the following combinations :—

(1) Pond's observations 1825–35, and those of the Greenwich Five-year Catalogue 1890.

(2) Airy's observations 1836–48, and the Madison observations 1887–92.

(3) The Pulkova Catalogue of 1845 and the Pulkova Catalogue 1885.

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These results, combined with weights thirteen, eight, and nine respectively, are exhibited in *A.J.*, No. 364, as corrections to the proper motions of Auwers and Boss, and have been incorporated in the following table for comparison with the values deduced from the Greenwich observations 1836–93.

The following, Table II., contains a list of stars whose proper motions have been redetermined either by Chandler or at Greenwich : columns three and four give the approximate R.A. and Decl. for 1890; column five gives the corrections applied by Auwers to Bradley's observed declinations reduced to 1755 from the table given on p. 252, vol. ii. of the *Neue Reduction der Bradleyschen Beobachtungen.* These corrections for the circumpolar stars have been combined with weights according to the number of observation above and below pole. Column six gives the corrections to Auwers-Bradley's proper motions in R.A. deduced from the Greenwich observations 1836 93. Columns seven and ten give similar corrections to Auwers-Bradley and Boss' proper motions in declination. Columns eight and nine give Chandler's and Boss' corrections referred to above.

All these quantities are arranged in order of right ascension.

Table III. gives the same quantities, arranged in order of declination.

Gr refers to the proper motions deduced from Greenwich observations 1836–93.

A refers to the proper motions deduced by Auwers from Bradley's observations.

B refers to the proper motions deduced by Boss.

C refers to the proper motions deduced by Chandler, *A.J.*, No. 361, p. 3.

Table II.

Order of Right Ascension.

Differences of Proper Motion in (1) *Right Ascension and Declination between Auwers-Bradley and Greenwich observations* 1836–93 ; *in* (2) *Declination between Auwers-Bradley and Chandler, " A.J.," No.* 364, *p.* 29 ; *in* (3) *Declination between Auwers-Bradley and Boss' Standard Catalogue ; and in* (4) *Declination between Boss' and Greenwich observations* 1836–93.

Ref. No.	Star's Name.	App. R.A. 1890.		App. Dec. 1890.		Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Diff. of P.M. Declination.			
								Gr−A.	C−A.	B−A.	Gr−B.
		h	m	°	′	″	s	″	″	″	″
1	α Andromedæ	0	3	28	3	+0·56	·0000	·000	−·009	−·011	+·011
2	γ Pegasi	0	8	14	6	+0·41	·0000	·000	−·006	−·006	+·006
3	α Cassiopeiæ	0	34	55	9	−0·42	...	...	−·002	−·003	...
3a	μ Andromedæ	0	50	37	9	−0·55	−·0038	−·019	...	−·042	+·023
4	β Andromedæ	1	4	35	0	−0·05	−·0005	−·027	...	−·038	+·011
5	α Arietis	2	1	22	9	−0·18	−·0004	−·016	−·018	−·017	+·001
6	α Ceti	2	57	3	7	+0·62	+·0010	·000	...	−·013	+·013
7	Aldebaran	4	30	16	2	+0·87	−·0008	·000	−·011	−·008	+·008
8	Rigel	5	9	−8	3	+0·31	·0000	·000	...	−·011	+·011

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Ref. No.	Star's Name.	App. R.A. 1890.		App. Dec. 1891.		Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Diff. of P.M. Declination.			
		h	m	°	′	″	s	Gr−A. ″	C−A. ″	B−A. ″	Gr.−B. ″
9	Capella	5	9	45	9	−0·63	−·0040	·000	−·006	−·010	+·010
10	β Tauri	5	19	28	5	+0·30	−·0004	+·015	+·002	−·001	+·016
11	α Orionis	5	49	7	4	−0·06	·0000	−·010	−·020	−·017	+·007
12	Sirius	6	39	−16	5	+0·18	−·0010	−·030	...	...	...
13	Castor	7	28	32	2	+0·16	−·0005	−·012	+·006	·000	−·012
14	Procyon	7	34	5	7	+0·24	−·0005	·000	...	...	...
15	Pollux	7	39	28	4	+0·31	−·0006	·000	−·010	−·006	+·006
16	Regulus	10	3	12	5	+0·30	·0000	−·018	−·017	−·019	+·001
17	α Ursæ Majoris	10	56	62	3	+0·09	...	...	·000	−·004	...
18	δ Leonis	11	8	21	1	−0·12	...	...	−·024	−·027	...
19	β Leonis	11	43	15	2	+0·86	·0000	−·020	...	−·021	+·001
20	δ Ursæ Majoris	12	10	57	6	−0·10	...	...	+·012	+·005	...
21	Spica	13	19	−10	6	0·00	+·0006	−·010	...	−·020	+·010
22	η Boötis	13	49	19	0	+0·10	−·0004	−·008	...	−·017	+·009
23	α Draconis	14	1	64	9	0·00	...	...	+·002	−·010	...
24	Arcturus	14	11	19	7	+0·06	+·0006	−·017	−·020	−·023	+·006
25	ϵ^2 Boötis	14	40	27	6	+0·41	·0000	+·016	...	−·009	+·025
26	β Ursæ Minoris *	14	51	74	6	−0·50	...	...	·000	−·009	...
27	α Coronæ	15	30	27	1	+0·61	·0000	·000	−·006	−·006	+·000
28	α Serpentis	15	39	6	8	−0·04	+·0003	−·008	−·015	−·022	+·014
29	ζ Herculis	16	37	31	8	+0·11	−·0014	−·025	...	−·009	−·016
30	α Herculis	17	10	14	5	+0·60	+·0006	·000	−·003	−·004	+·004
31	α Ophiuchi	17	30	12	6	+0·24	+·0004	−·014	−·017	−·020	+·006
32	γ Draconis	17	54	51	5	+0·20	+·0004	·000	...	−·002	+·002
33	α Lyræ	18	33	38	7	−0·18	·0000	−·020	−·020	−·023	+·003
34	β Lyræ	18	46	33	2	+0·15	+·0005	−·024	−·024	−·034	+·010
35	ζ Aquilæ	19	0	13	7	+0·35	...	...	−·016	−·014	...
36	δ Draconis	19	13	67	5	+0·26	...	...	+·003	+·006	...
37	γ Aquilæ	19	41	10	3	−0·20	+·0008	−·020	−·019	−·016	−·004
38	α Aquilæ	19	45	8	6	−0·28	·0000	−·020	−·014	−·014	−·006
39	β Aquilæ	19	50	6	1	+0·24	+·0014	−·008	−·016	−·019	+·011
40	α^2 Capricorni	20	12	−12	9	+0·12	+·0020	−·016	...	−·017	+·001
41	α Cygni	20	38	44	9	+0·60	·0000	−·015	−·010	−·011	−·004
42	α Cephei	21	16	62	1	0·00	...	...	+·026	+·017	..
43	β Cephei	21	27	70	1	+0·25	...	...	+·014	+·007	...
44	α Aquarii	22	0	−0	9	+0·98	+·0004	·000	...	−·016	+·016
45	α Pegasi	22	59	14	6	+0·41	·0000	−·016	−·018	−·020	+·004

* One observation only in Bradley.

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Table III.

Order of Declination.

Difference of Proper Motion from Table I.

Ref. No.	Star's Name.	Approx. Dec. 1890.		Approx. R.A. 1890.		Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Difference of P.M. Declination.			
								Gr−A.	C−A.	B−A.	Gr−B.
		°	′	h	m	″		″	″	″	″
12	Sirius	−16	5	6	39	+0·18	−·0010	−·030	...	...	...
48	α^2 Capricorni	−12	9	20	12	+0·12	+·0020	−·016	...	−·017	+·001
21	Spica	−10	6	13	19	0·00	+·0006	−·010	...	−·0200	+·010
8	Rigel	−8	3	5	9	+0·31	·0000	·000	...	−·011	+·011
44	α Aquarii	−0	9	22	0	+0·98	+·0004	·000	...	−·016	+·016
6	α Ceti	+3	7	2	57	+0·62	+·0010	·000	...	−·013	+·013
14	Procyon	5	7	7	34	+0·24	−·0005	·000	...	...	...
39	β Aquilæ	6	1	19	50	+0·24	+·0014	−·008	−·016	−·019	+·011
28	α Serpentis	6	8	15	39	−0·04	+·0003	−·008	−·015	− 022	+·014
11	α Orionis	7	4	5	49	−0·06	·0000	−·010	−·020	−·017	+·007
38	α Aquilæ	8	6	19	45	−0·28	·0000	−·020	−·014	−·014	−·006
37	γ Aquilæ	10	3	19	41	−0·20	+·0008	−·020	−·019	−·016	−·004
16	Regulus	12	5	10	3	+0·30	·0000	−·018	−·017	−·019	+·001
31	α Ophiuchi	12	6	17	30	+0·24	+·0004	−·014	−·017	−·020	+·006
35	ζ Aquilæ	13	7	19	0	+0·35	...	...	−·016	−·014	...
30	α Herculis	14	5	17	10	+0·60	+·0006	·000	−·003	−·004	+·004
2	γ Pegasi	14	6	0	8	+0·41	·0000	·000	−·006	−·006	+·006
45	α Pegasi	14	6	22	59	+0·41	·0000	−·016	−·018	−·020	+·004
19	β Leonis	15	2	11	43	+0·86	·0000	−·020	...	− 021	+·001
7	Aldebaran	16	2	4	30	+0·87	−·0008	·000	−·011	−·008	+·008
22	η Boötis	19	0	13	49	+0·10	−·0004	−·008	...	−·017	+·009
24	Arcturus	19	7	14	11	+0·06	+·0006	−·017	−·020	− 023	+·006
18	δ Leonis	21	1	11	8	−0·12	...	...	−·024	−·027	...
5	α Arietis	22	9	2	1	−0·18	−·0004	−·016	−·018	−·017	+·001
27	α Coronæ	27	1	15	30	+0·61	·0000	·000	−·006	−·006	+·006
25	ϵ^2 Boötis	27	6	14	40	+0·41	·0000	+·016	...	−·009	+·025
1	α Andromedæ	28	3	0	3	+0·56	·0000	·000	−·009	−·011	+·011
15	Pollux	28	4	7	39	+0·31	−·0006	·000	−·010	−·006	+·006
10	β Tauri	28	5	5	19	+0·30	−·0004	+·015	+·002	−·001	+·016
29	ζ Herculis	31	8	16	37	+0·11	−·0014	−·025	...	−·009	−·016
13	Castor	32	2	7	28	+0·16	−·0005	−·012	+·006	·000	−·012
34	β Lyræ	33	2	18	46	+0·15	+·0005	−·024	−·024	−·034	+·010
4	β Andromedæ	35	0	1	4	−0·05	−·0005	−·027	...	−·038	+·011
3a	μ Andromedæ	37	9	0	50	−0·55	−·0038	−·019	...	−·042	+·023

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Ref. No.	Star's Name.	Approx. Dec. 1890.		Approx. R.A. 1890.		Auwers' corr. to Bradley. Decl.	Diff. of P.M. in R.A. Gr−A.	Difference of P.M. Declination.			
								Gr−A.	C−A.	B−A.	Gr−B.
		°	′	h	m	″		′	″	″	″
33	α Lyræ	38	7	18	33	−0·18	·0000	−·020	−·020	−·023	+·003
41	α Cygni	44	9	20	38	+0·60	·0000	−·015	−·010	−·011	−·004
9	Capella	45	9	5	9	−0·63	−·0040	·000	−·006	−·010	+·010
32	γ Draconis	51	5	17	54	+0·20	+·0004	·000	...	−·002	+·002
3	α Cassiopeiæ	55	9	0	34	−0·42	...	...	−·002	−·003	...
20	δ Ursæ Majoris	57	6	12	10	−0·10	...	...	+·012	+·005	...
42	α Cephei	62	1	21	16	0·00	...	...	+·026	+·017	...
17	α Ursæ Majoris	62	3	10	56	+0·09	...	...	·000	−·004	...
23	α Draconis	64	9	14	1	0·00	...	...	+·002	−·010	...
36	δ Draconis	67	5	19	13	+0·26	...	...	+·003	+·006	...
43	β Cephei	70	1	21	27	+0·25	...	...	+·014	+·007	...
26	β Ursæ Minoris*	74	6	14	51	−0·50	...	...	·000	−·009	...

* One observation only in Bradley.

The following general conclusions, making due allowance for the number of stars under discussion, may be drawn from these tables :—(1) That the proper motions deduced by Chandler and Boss agree very closely. (2) That there are systematic discordances either in the proper motions deduced by Auwers or in those deduced by Chandler and Boss. (3) That the Greenwich proper motions lie between those of Auwers and those of Chandler and Boss, and do not support the latter in attributing the systematic discordances as all due to Auwers. (4) That the corrections applied by Auwers to Bradley's observations (as far, at any rate, as the declinations covered by the clock-star system) are not in the main otherwise than beneficial, though they aggravate the large discordances shown to exist in the zones +6°·8 to 0°·3 and +35° to +38° (see Professor Newcomb's paper on Boss' System of Declinations, *A.J.*, No. 365, p. 34). (6) That in any case the mean effect of these corrections is very small, +0″·18.

Now, if we take the mean of columns 5, 7, 9, and 10 of Table II. for those stars only whose proper motions have been re-determined at Greenwich, not including *Sirius* or *Procyon*, we shall get

Gr−A.	B−A.	Gr−B.	Effect of Auwers' Corr. on P.M.
″	″	″	″
−·0088	−0·0153	+·0068	−·0016

Thus it would appear that the mean effect of Auwers' correction is to reduce the quantities Gr−A and B−A by ″·0016.

Now from Chandler's papers, *A.J.*, 364, p. 29, we find that the mean difference between Chandler's and Boss' systems of proper motions is C−B=+″·0021, which would make Gr−C=+″·0047,

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and from his paper, *A.J.*, No. 361, we learn that in the reduction of the Greenwich mural circle observations he has adopted 38″·42 for the mean value of the latitude. From independent sources we know the mural circles were 0″·07 north of the present transit circle, which makes this adopted value of the mean latitude referred to the present transit circle 38″·35, whereas the value adopted at Greenwich in the reductions of the Five-year Catalogue, 1890, is 38″·10. For the purpose of obtaining values of the proper motion one or other of these sets of observations should be altered. Correcting Chandler's value, and taking fifty-five years as about the period over which the observations extend, and allowing for Chandler's weights, we get a correction of +0″·0031 to Chandler's proper motions ; a quantity which satisfactorily accords with the value +·0047 given for Gr − C.

If we take the mean values of the three different determinations of all the proper motions given by Chandler, *A.J.*, No. 361, p. 3, we get

Gr. (5 year 1890) and Pond.	Madison and Airy.	Pulkova 1845 and 1885.
−0″·111	−0″·112	−0″·105

from which it appears that the correction to the mean of the first two systems to reduce to that of Pulkova is +″·0065 ; a value which also confirms the difference +″·0047 shown to exist between Chandler and Greenwich, as also the validity of the assumption of an alteration of Chandler's Pond-Airy reductions.

Finally, in *A.J.*, No. 365, Professor Newcomb has pointed out that from the planetary theories (*Astronomical Constants*, p. 89) the general correction to Boss' system = +0″·09 +0″·42 T, where T is the time from 1850 in terms of the century as unit ; also that the value of the secular term may be in error some ±0″·30. This, again, confirms the mean correction of +0″·0068 to Boss' proper motions given by the Greenwich system 1836–93, and testifies to the general correctness of the latter system.